

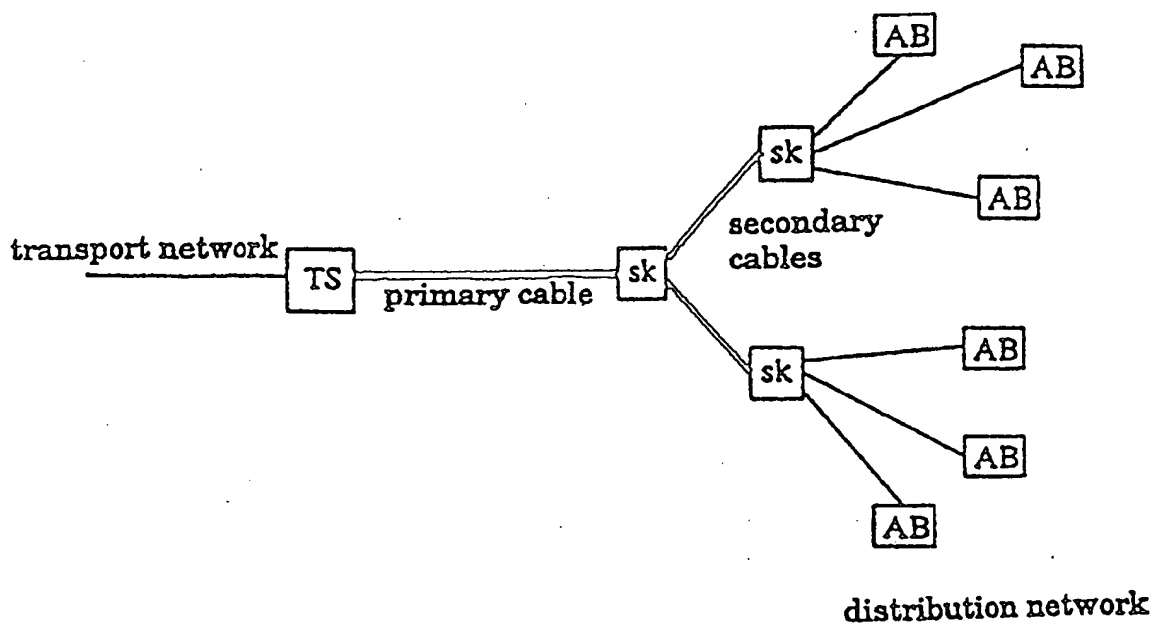
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H04L 5/06</b>		<b>A1</b>	(11) International Publication Number: <b>WO 97/06619</b>
			(43) International Publication Date: 20 February 1997 (20.02.97)
(21) International Application Number: PCT/SE96/00935 (22) International Filing Date: 10 July 1996 (10.07.96) (30) Priority Data: 9502775-1                      4 August 1995 (04.08.95)                      SE (71) Applicant (for all designated States except US): TELIA AB [SE/SE]; S-123 86 Farsta (SE). (72) Inventor; and (75) Inventor/Applicant (for US only): ISAKSSON, Mikael [SE/SE]; Borgmästarevägen 7, S-973 42 Luleå (SE). (74) Agent: KARLSSON, Berne; Telia Research AB, Rudsjöterrassen 2, S-136 80 Haninge (SE).		(81) Designated States: NO, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published <i>With international search report.          Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: PROCEDURE TO SUPPRESS NEAR-END CROSSTALK AT BIDIRECTIONAL COMMUNICATION IN WIRE NETWORK



## (57) Abstract

The invention relates to a procedure to suppress near-end crosstalk at bidirectional broadband communication in wire network, where a cable with at least one pair of wires connects the telephone exchange side and the subscriber side. According to the invention orthogonal subcarriers are utilized in the two transmission directions, for instance by use of DMT line coding technology (Discrete Multitone). The transmission can be symmetric or asymmetric with different numbers of carriers in different transmission directions. The invention solves the problem of near-end crosstalk and echo in the system and increases the transmission capacity, especially at symmetric communication.

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TITLE OF THE INVENTION: PROCEDURE TO SUPPRESS NEAR-END  
CROSSTALK AT BIDIRECTIONAL  
COMMUNICATION IN WIRE NETWORK

#### TECHNICAL FIELD

The present invention relates to a procedure to suppress near-end crosstalk at bidirectional communication in wire networks. The invention makes possible to suppress near-end crosstalk and echoes at broadband communication over copper cable in an access network by utilizing the transmission technology Discrete Multi Tone (DMT).

DMT is a transmission technology or line coding technology for wire-based tele- and data communication networks and is fundamentally the same technology as OFDM (Orthogonal Frequency Division Multiplexing), which is the corresponding method for the technology in connection with radio.

#### PRIOR ART

A problem with the technology of today is that it is considerably easier to develop technology for asymmetric communication in access networks than technology for symmetric communication. This is due to that disturbances in the form of near-end crosstalk arise between adjacent copper pairs in the same copper cable if the same frequency is utilized in both transmission directions. At asymmetric communication a broadband information is transmitted from the fixed network to the subscriber, whereas a considerably lower capacity can be transmitted from the subscriber to the network. For services which require broadband transmission in both directions it is however difficult and complicated to attain a sufficient transmission capacity via the copper cable network.

One aim with the present invention is among other things to solve the above presented problem and provide a procedure which allows a more equalized distribution of the transmission capacity of the

copper network by suppressing near-end crosstalk at broadband communication in a coppercable based access network.

USA 5 241 538 can be regarded to represent the most closely related technology. The document relates to reduction of crosstalk. A crosstalk reduction circuit produces from a main signal a crosstalk correction signal of the same amplitude as the crosstalk from the main signal to a subsignal, but with reversed phase. The correction signal is added to the subsignal. A first modulation circuit modulates a subcarrier by an output signal from the crosstalk reduction circuit. A frequency multiplexor circuit frequency-multiplexes the main signal and the modulated subcarrier to make a frequency-multiplexed signal. A second modulation circuit frequency-modulates a main carrier by the frequency-multiplexed signal to make a frequency-modulated signal. The frequency-modulated signal is transmitted through the transmission line. This document does not mention use of orthogonal subcarriers by utilizing DMT-technology.

The present invention solves the above mentioned problem by utilizing DMT-technology as transmission technology. The possibility of the DMT-technology to frequency-multiplex the information orthogonally in the frequency plane is utilized. By distributing subcarriers on the two transmission directions, the near-end crosstalk can be suppressed, which results in that more information can be transmitted per subcarrier.

## SUMMARY OF THE INVENTION

The present invention consequently provides a procedure to suppress near-end crosstalk at bidirectional communication in wire networks, including a cable between a first side and a second side. The cable includes at least one wire pair for telecommunication.

According to the invention, different carriers are used in the two transmission directions, and the subcarriers are orthogonal. The number of subcarriers in each transmission direction can be chosen either so that an asymmetric or a symmetric system is obtained.

Preferably Discrete Multitone Technology, DMT, with guard space between symbols is utilized. Transmitters on both sides should be time synchronized within a guard space interval.

The invention is defined in details in enclosed patent claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will after this be described in detail with reference to enclosed drawings, in which

Figure 1 is a block diagram over the access network in telecommunication system,

Figure 2 is a diagram over the time structure for the DMT-technology,

Figure 3 is a diagram over orthogonal carriers in the frequency plane for the DMT-technology,

Figure 4 illustrates near-end crosstalk and far-end crosstalk between wire-pairs in a copper cable,

Figure 5 is a diagram over attenuation, near-end crosstalk and far-end crosstalk as function of the frequency,

Figure 6 illustrates margins for orthogonality at the DMT-technology,

Figure 7 is a diagram which illustrates examples of distribution of subcarriers according to the present invention, and

Figure 8 shows schematically the crosstalk situation in the fixed side and the subscriber side in a telecommunication network.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a general procedure to suppress near-end crosstalk and echoes in systems for broadband communication over copper cable by utilizing DMT line coding technology. The invention can be utilized to increase the capacity at symmetric communication, i.e. the same transmission capacity in both directions, to and from subscriber. The invention replaces functions such as echo cancellers and crosstalk cancellers.

DMT stands for "Discrete Multitone" and is a transmission technology, or line coding technology, for wirebased networks. DMT is basically the same technology as OFDM (Orthogonal Frequency Division Multiplexing), which is a term which is used in radio connections.

It has proved to be considerably easier to develop technology for asymmetric communication (ADSL) in the access network than technology for symmetric communication (HDSL). The reason is that disturbances

in the form of Near End CrossTalk (NEXT) arise between adjacent copper pairs in the same copper cable, if the same frequency band is used in both transmission directions. At asymmetric communication a broadband information is transmitted from the fixed network to the subscriber, whereas a considerably lower capacity can be transmitted from the subscriber to the network, at which the problem with the near-end crosstalk is reduced.

The ADSL-technology is suitable for services of type "Video on Demand", distance education, games etc, which only need broadband transmission in one direction. For services which require broadband transmission in both directions, type video conferences and data communication, it is difficult and complicated to attain a sufficient capacity via the copper network.

The present network is based on a concept which contributes to a more "solidary" distribution of the transmission capacity of the copper network by utilizing the possibilities of the DMT-technology to frequency-multiplex the information orthogonally in the frequency plane. By distributing the subcarriers on the two transmission directions the near-end crosstalk can be suppressed, which results in that more information can be transmitted per subcarrier. The invention requires a comparatively good time synchronization in the access network, and sufficiently large guard spaces within a signal interval.

In order to facilitate the understanding of the invention is after this a general description of a typical access network in a telecommunication system and of the DMT-technology given.

In Figure 1 is shown an access network. The access network consists in principle exclusively of twisted copper pairs between the telephone exchange/station (TS) and the subscribers (AB). The topology is of star structure.

From the telephone exchange TS come primary cables containing from a few hundred up to several thousand pair cables; one unique pair of copper to each subscriber AB. The primary cable after that is split in cabinets (SK) into secondary cables, which after that are split into the so called distribution network, closest to the subscribers. The telephone cables in the distribution network most often contain between 5 and 100 copper pairs.

The DMT-technology will now be explained with reference to Fig.2.

In most existing systems based on DMT/OFDM a guard space is utilized between the symbols. The guard space has the task of absorbing the time dispersion between two following symbols, and to allow a certain time variation at the sampling of the symbol. If a 1024 points FFT (Fast Fourier Transform) is utilized, the symbol is sampled 1024 times. The number of samples for the guard space can be between 0 and 1/4 of the FFT-length.

The guard space is filled up in the time domain by repeated data, i.e. the first part of the symbol. Since the FFT-operation is cyclic, this makes that the starting point for sampling of the symbol can be varied within the signal interval, i.e. the symbol time plus the guard space, without information being lost. This can also be expressed as that the symbols keep their orthogonality between them in the frequency plane.

If, on the contrary, the sampling is made over the joint between two symbols, the orthogonality is destroyed and the possibility for symbol detection.

This gives a condition of the procedure according to the invention, as is explained more in detail with reference to Figure 6.

The orthogonality of the different subcarriers in the frequency plane is shown in Figure 3. A subcarrier has been marked by circles for the sake of clarity.

The orthogonality is obtained by the spectrum form of each subcarrier following a  $\sin(x)/x$ -function, or sinc-function. Each subcarrier has a maximum and zero-passings where other channels have maxima.

If the sampling to the FFT-operation in the receiver is not made within the signal interval, the orthogonality is destroyed, i.e. the condition for zero-passings is not fulfilled, which makes detection of the symbols impossible.

Figure 4 illustrates crosstalk between copper wire pairs in a cable. What in the first hand restricts the data transmission over copper cable is crosstalk from adjacent copper pairs within the same cable, in combination with that the received signal is strongly attenuated. There are two different cases of crosstalk; Near End Cross Talk (NEXT) and Far End Cross Talk (FEXT).

Near-end crosstalk is considerably more serious than the far-end crosstalk. The reason is that the received signal in the receiver Rx is strongly attenuated due to the length of the cable, which results

in that the crosstalk from the transmitter Tx becomes strong in relation to the level of the received signal. This also can be expressed as that the Signal Interference Ratio (SIR) becomes low. Far-end crosstalk arise from signals in adjacent copper pairs with the same transmission direction as the signal the receiver Rx receives. This makes that the far-end crosstalk is attenuated to the same extent as the signal when it propagates through the cable, and the signal/interference ratio becomes considerably higher than for the near-end crosstalk. If the two transmission directions are in separate frequency-bands, the near-end crosstalk can be avoided, which one utilizes within asymmetric communication.

The total crosstalk which arises is of course the sum of crosstalk from all copper pairs within the same cable.

Both near- and far-end crosstalk are increasing functions of the frequency as is shown in Figure 5. The attenuation characteristic of the pair cable is also included in the same diagram. The distance (Carrier Interference Ratio, CIR), or the area, between the attenuation curve and the crosstalk curves is a measure of how high transmission capacity that can be achieved.

If near-end crosstalk is the dominating type of disturbance, a considerably lower transmission capacity is obtained when far-end crosstalk dominates.

CIR, i.e. the distance between the attenuation curve and the crosstalk curves rapidly decreases for higher frequencies. This is utilized in the DMT-technology in that way that for subcarriers at low frequencies and with high CIR more bits/symbol are transmitted than for subcarriers at high frequencies and low CIR. The technology is called "bit-loading". If far-end crosstalk dominates, considerably more bits can be transmitted per symbol than if near-end crosstalk dominates.

The idea of the invention is based on the following conditions:

Condition 1. All transmitters in the access network, both on the subscriber side and in the telephone exchange, are time synchronized within a guard space interval.

The condition implies that the near-end crosstalk always is orthogonal with the received signal. This is illustrated in Figure 6. The sampling interval of the received symbol is within the signal interval of all symbols that are transmitted in opposite direction.



The margins for that the orthogonality conditions shall be met with before and after the sampling interval are indicated in the figure.

Condition 2. Different subcarriers are used for the two  
5 transmission directions.

The condition implies that all near-end crosstalk have zero-places in the subcarriers which contain information in the received signal. This is illustrated in Figure 7.

At the top in Figure 7 is shown all utilized subcarriers where the  
10 spectrum form for the sinc-function has been approximated with a triangle. The directions of the arrows symbolize the transmission direction for the different subcarriers.

In the Figure 12 subcarriers are utilized, 6 in each transmission  
15 direction. The example is chosen so that every other carrier is utilized in the upward direction (from subscriber to telephone exchange), and every other is utilized in the downward direction. This choice is not a requirement for the method according to the invention, but the requirement is that different carriers are utilized. The method also allows that the number of carriers which  
20 are utilized in the two transmission directions can vary, which gives asymmetric communication.

At perfect synchronization the CIR-margin for each received symbol  
(subcarrier) is decided by the far-end crosstalk curve in Figure 5,  
instead of by the near-end crosstalk curve, which gives considerably  
25 higher transmission capacity per subcarrier.

In Figure 8 is shown a sketch of a how incoming symbols are  
disturbed by outgoing, on the one hand at the telephone exchange, and  
at the other at the subscriber. The time synchronization at the  
telephone exchange is easy to achieve, because all hardware for  
30 transmission over all copper pairs is collected. The time synchronization on the subscriber side is a bit more difficult, because time synchronization is made on physically separate places, and that the different copper pairs have different lengths.

The time synchronization can be achieved in different ways, as is  
35 realized by an expert in the field. The invention is only restricted by the following patent claims.

## PATENT CLAIMS

1. Procedure to suppress near-end crosstalk at bidirectional communication in wire networks, including a cable between a first side and a second side, which cable includes at least one pair of wires for telecommunication, characterized in that different subcarriers are used in the two transmission directions, at which the subcarriers are orthogonal.

2. Procedure according to patent claim 1, characterized in that a number of subcarriers are transmitted in each transmission direction, at which every other subcarrier is utilized in respective direction.

3. Procedure according to patent claim 1, characterized in that a number of subcarriers are utilized, at which the number of carriers which are utilized in one transmission direction is larger than in the other transmission direction.

4. Procedure according to any of the previous patent claims, characterized in that the transmission utilizes discrete multitone technology (DMT) with guard space between symbols.

5. Procedure according to patent claim 4, characterized in that transmitters on both sides are time synchronized within a guard space interval.

6. Procedure according to any of the previous patent claims, characterized in that the spectrum form for each subcarrier follows a function  $\sin(x)/x$ , and each subcarrier has a maximum and zero-passings where other subcarriers have maxima.

7. Procedure according to any of the previous patent claims, characterized in that the first side is at a telephone exchange (station, TS) and the other side is the subscriber side (AB).

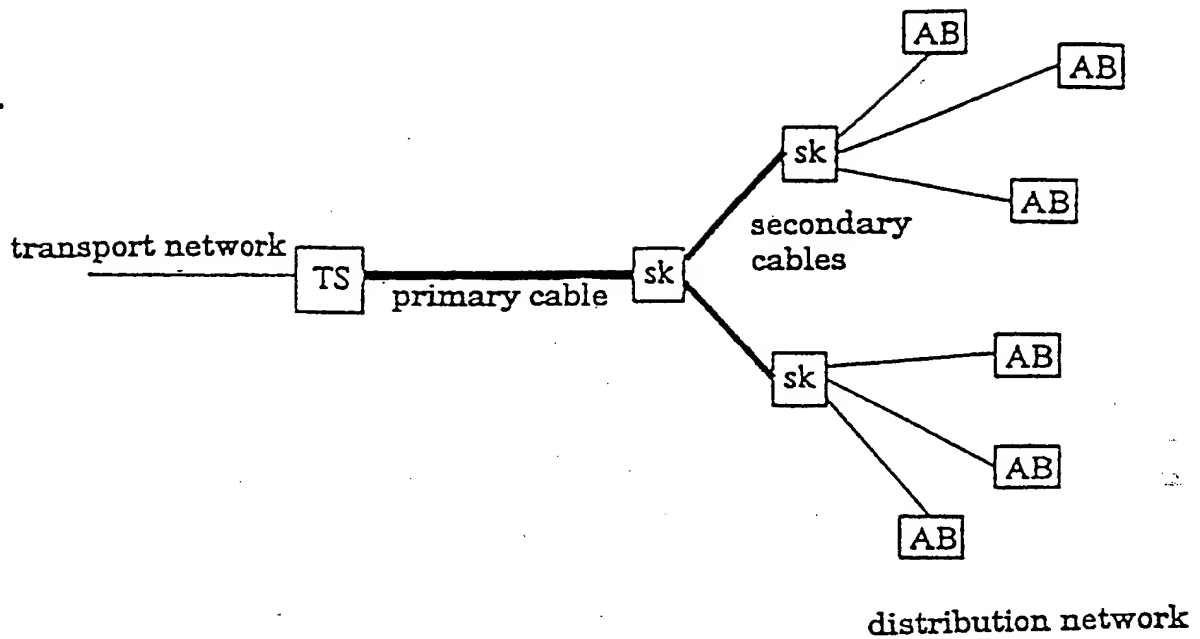


Fig. 1

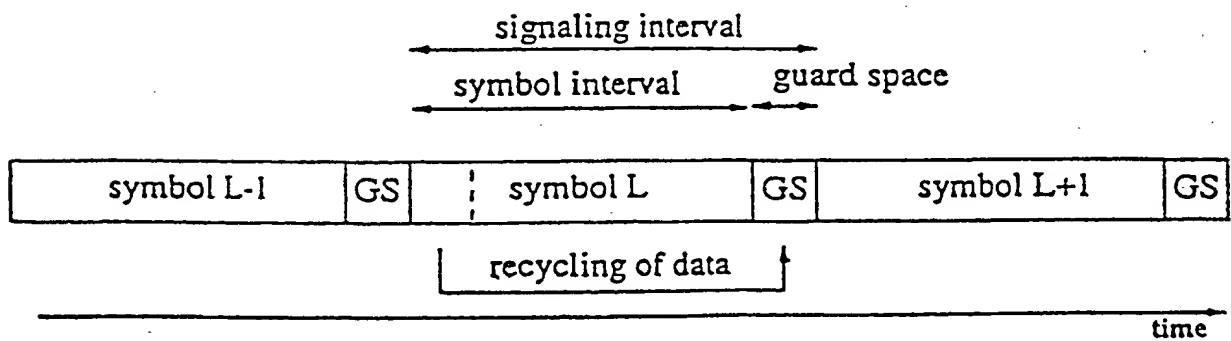


Fig. 2

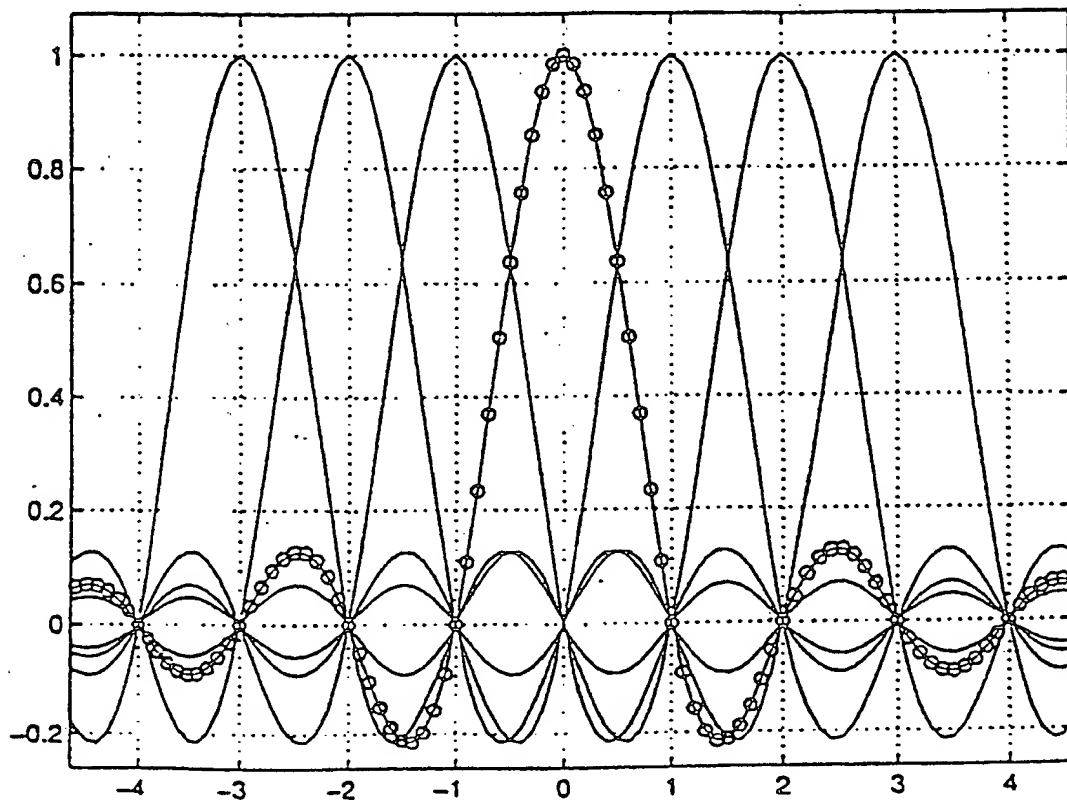


Fig. 3

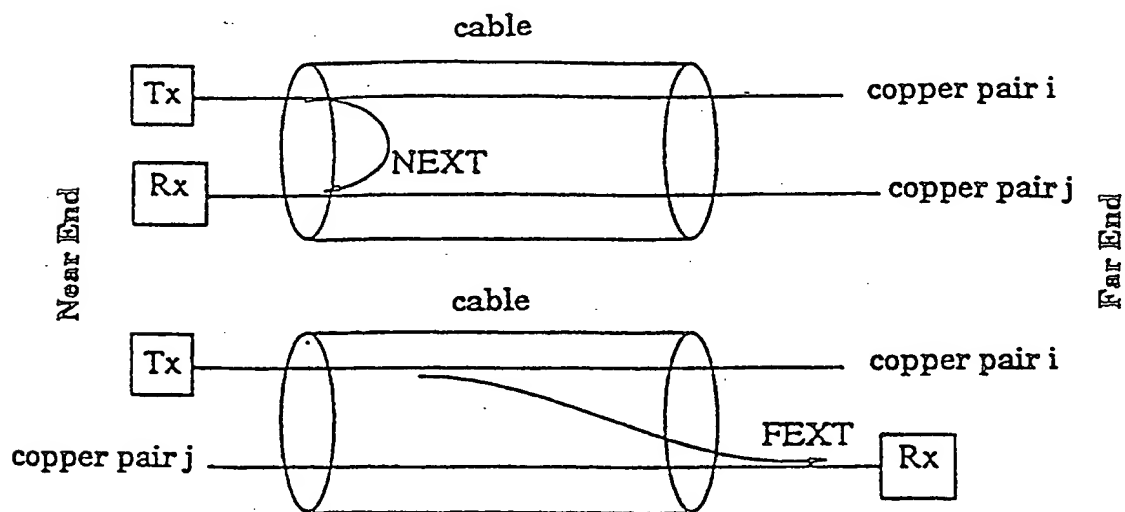


Fig. 4

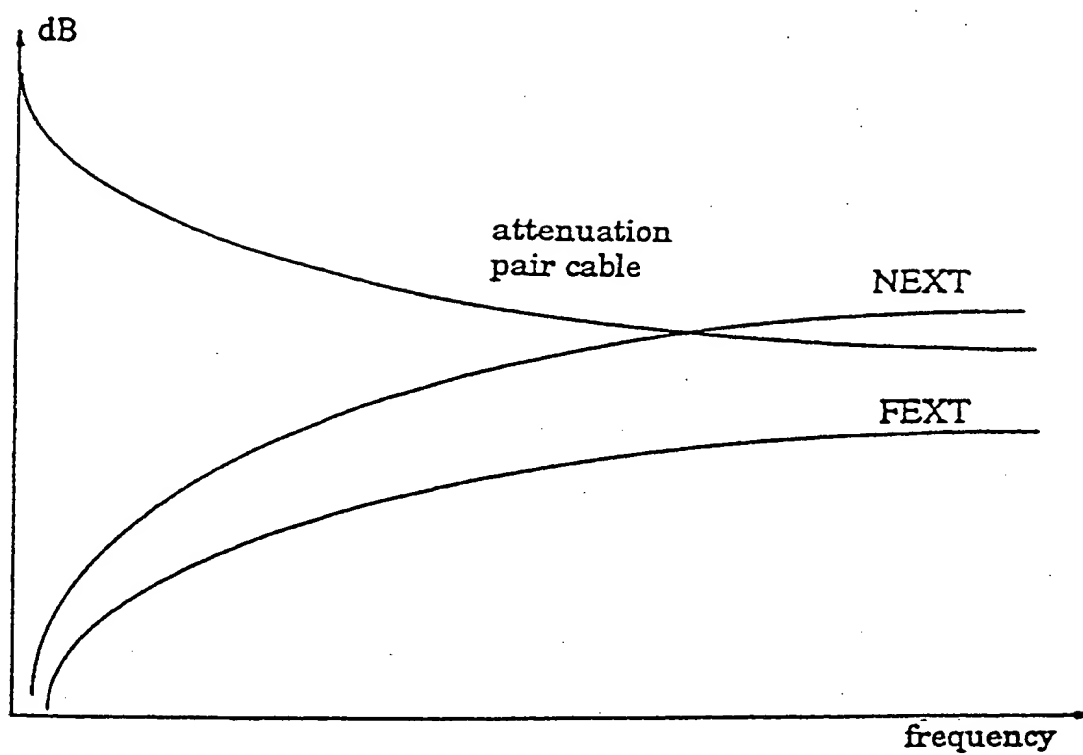


Fig. 5

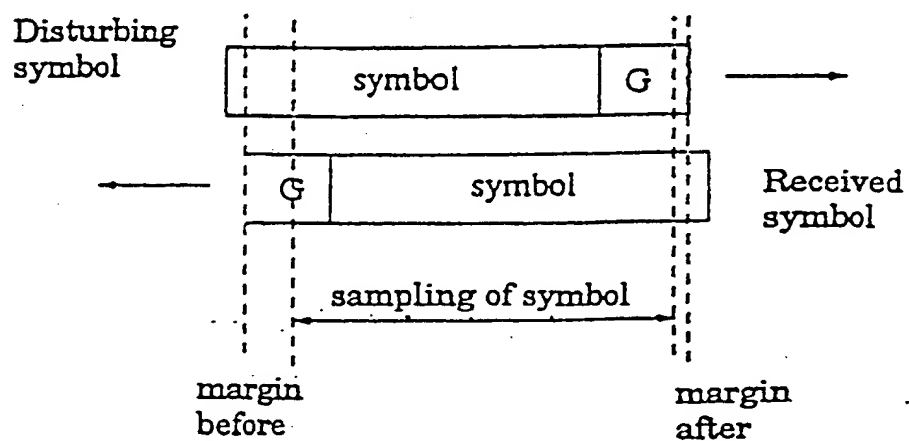


Fig. 6

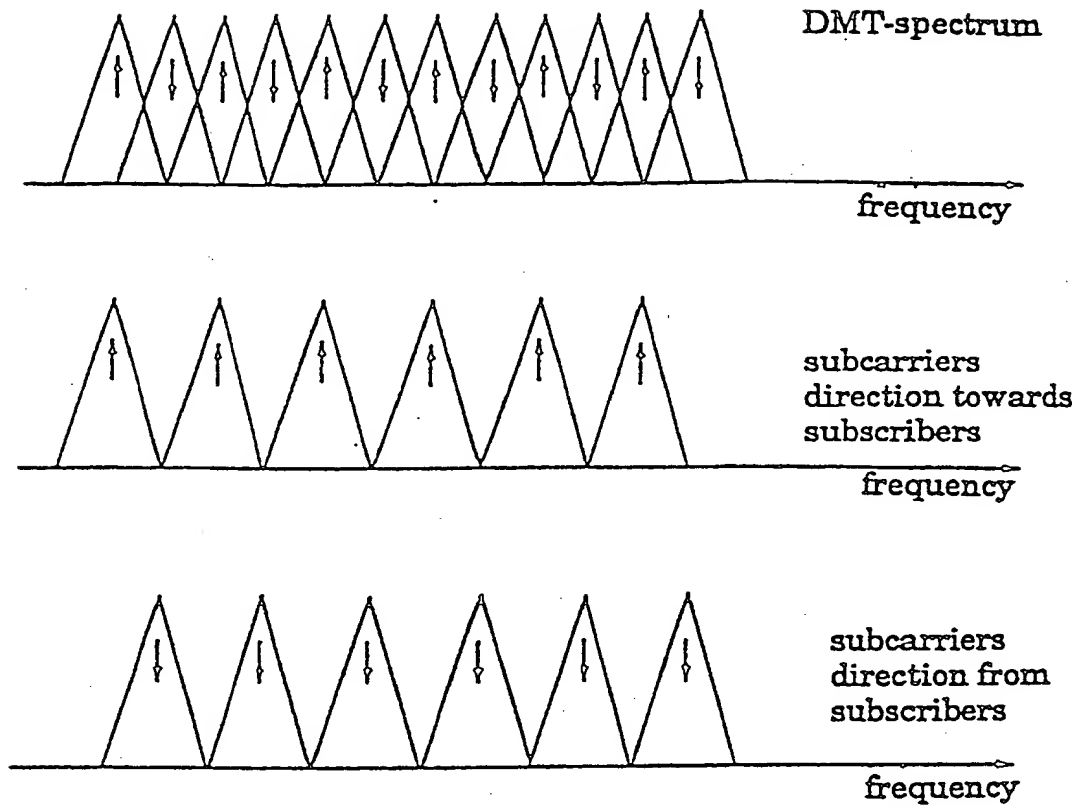


Fig. 7

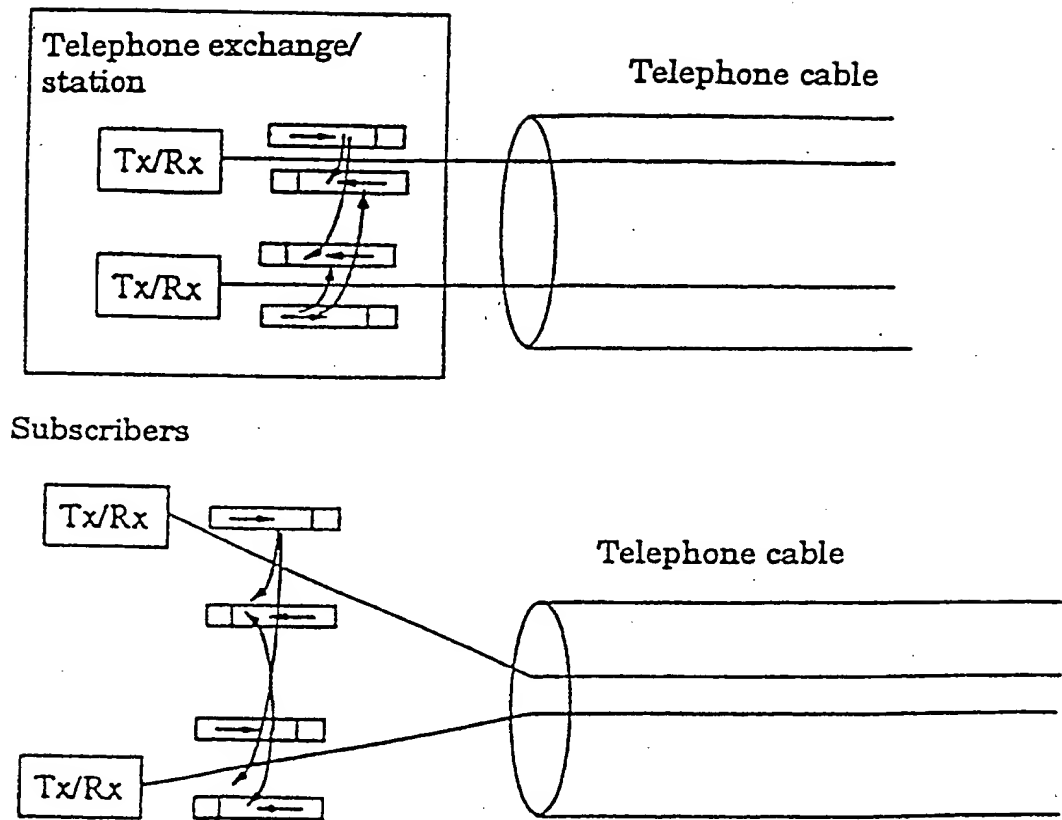


Fig 8

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 96/00935

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 5/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IEEE TRANSACTIONS ON BROADCASTING., Volume 41, No 1, March 1995, WILLIAM Y. ZOU et al, "COFDM: An overview", page 1 - page 6, figures 2,3, see esp. ch. 2,3,7 --	1-7
A	EP 0616445 A1 (FRANCE TELECOM.), 21 Sept 1994 (21.09.94), page 3, line 19 - line 41, abstract --	1-7
A	IEEE TRANSACTIONS ON COMMUNICATIONS., Volume 33, No 7, July 1985, LEONARD J. CIMINI, JR., "ANALYSIS AND SIMULATION OF A DIGITAL MOBILE CHANNEL USING ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING.", page 665 - page 675, see esp. ch.2. -- -----	1-7

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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# INTERNATIONAL SEARCH REPORT

### Information on patent family members

28/10/96

International application No.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0616445	21/09/94	FR-A,B- 2702904	23/09/94

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